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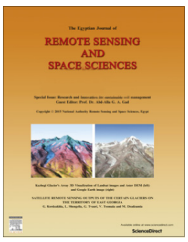

RESEARCH PAPER

Land capability classification of some western desert Oases, Egypt, using remote sensing and GIS

Abd-Alla Gad *

National Authority for Remote Sensing and Space Sciences (NARSS), 23, Josef Brows Tito, El-Nozha El-Gededa, P. Box 1564-Alf Maskan, Cairo, Egypt

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Abstract Two desert Oases (i.e. Al-Kharga and Al-Dakhla), located in the western desert of Egypt, were selected as case studies. Soil, ETM$^+$ satellite images, climatic and landscape database, were integrated through a GIS model. Digital Elevation Model (DEM) was elaborated using SRTM space images, in addition to spot heights and contour lines, derived from topographic maps. The created land resource database was used to evaluate and map land capabilities on bases of FAO (1985) methodology.

The obtained data indicate that the highly capable soils represent 24.5% of Al-Kharga Oases and 19.2% of Al-Dakhla Oases. These soils are associated with the *Typic Haplotorrerts* and *Typic Torrifluvents* sub-great groups. The moderately capable soils represent 1.5% of the total area of Al-Kharga Oases and 6.1% of Al-Dakhla Oases. They were found to be associated with sub-great group soil *Typic Torriorthents*. The low capable soils represent 36.0% of Al-Kharga Oases total area and 20.3% of Al-Dakhla Oases; this class is associated with the soils of *Torripsamments* great group. The rest of the Oases are considered as non-capable soils or rock land, representing 38.0% of Al-Kharga Oases total area and 54.5% of Al-Dakhla Oases.

It could be concluded that the desert Oases are sustainable areas, which might have potential importance supporting the national development programs. Integrating remote sensing data with digital soil map, using GIS, led to the elaboration of successful land capability classification mapping.

1. Introduction

1.1. General

The term "Oases" was initially applied to small areas in Africa and Asia, typically supporting trees and cultivated crops with water supply from springs and from water seepage, originating at some distance (Gad, 2008). The main objective of this study is to develop a GIS based model for land capability classification in the western desert Oases.

Land Capability is the "quality" of land to produce common cultivated crops and pasture plants without deterioration over a long period of time (FAO, 1983). Wells (2001) defined land capability as "*the ability of land to support a particular type of use without causing permanent damage*". Land capability classification categories are subdivided into capability classes and subclasses. The soil, as the main component of land

* Mobile: +20 122 3568182.
E-mail addresses: abdallagad1@gmail.com, agad@narss.sci.eg.
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capability classification system, takes into consideration soil limitations, risk of damage when soils are used, and the way in which soils respond to treatment. Capability classes range from Class I soils, which have few limitations for agriculture, to Class VIII soils, which are unsuitable for agriculture. The land capability classification provides a guide for the assessment of soil constraints and land management recommendations for use at a range of scales including state, catchment and the property planning level (Murphy et al., 2004).

The first land capability classification (LCC) was developed, in USA, by Soil Conservation Service (now called the Natural Resource Conservation Service) in the late 1930's and early 1940's. The LCC is a three level classification, consisting of capability class, capability subclass, and capability unit. Land was placed in a class based on landscape, slope, soil depth, texture and acidity. Subclasses were identified for special limitations such as erosion, excess wetness, problems in the rooting zone, and climatic limitation. Land capability units were identified as grouping of soils with similar levels of yield and common requirements for land management. Procedures to classify soils, according to the LCC, needs an elaboration of detailed soil survey in addition to information on slope, erosion, and land use.

There are many approaches in land capability classification according to the collected samples and land cover data. The earliest formal systems, based on scores for soil and land properties, were developed in Germany in the 1930's. In recent studies, the collected soil samples are chemically and physically analyzed while some soil parameters are measured in the field or interpreted from the enhanced ETM$^+$ images. These parameters include climatic condition, texture, soil depth, $CaCO_3$%, gypsum%, gravel%, salinity, alkalinity, slope and drainage pattern (Stori, 1964; Sys, 1991; Arnous and Hassan, 2006). These parameters are assessed by applying remote sensing and GIS techniques (Panhalkar, 2011), as they are powerful tools for collecting information at a very low cost and high accuracy. Moreover, the use of GIS lies in its capability for modeling, constructing models of the real world from the digital database and using the models to simulate a given scenario.

Progress in GIS technologies allows to process large amounts of spatial data and to provide more accurate and accessible information about the land (Arnous and Hassan,

Figure 1 ETM$^+$ Landsat images of Al-Kharga Oases (A).

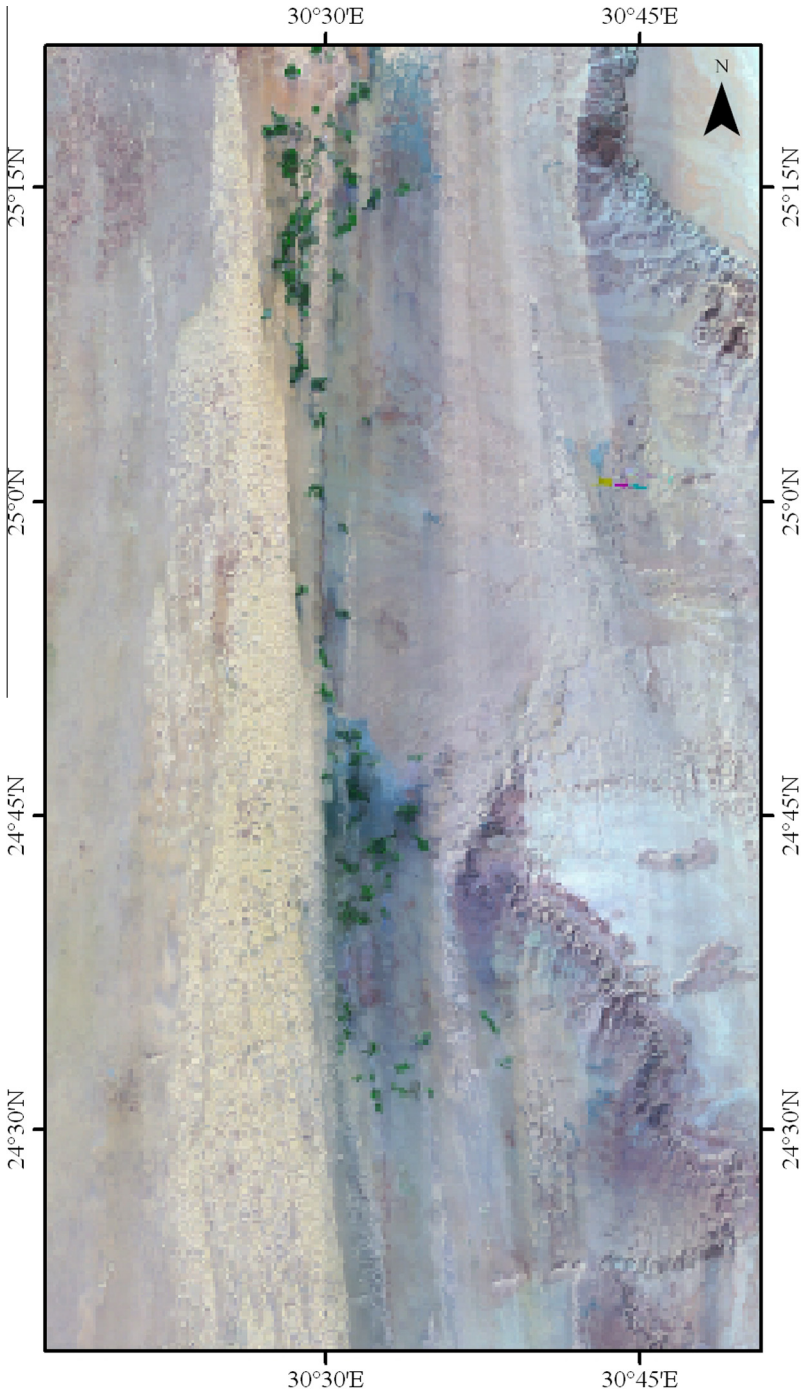

Figure 2 ETM$^+$ Landsat images of Al-Kharga Oases (B).

2006). The use of spatial analyses techniques, in evaluating the land capability, support the production of multi-thematic maps. The created database would help in outlining the limiting factors, accordingly suitable suggestions for sustainable agricultural use (Ali et al., 2007).

2. Environmental setting of study areas

Al-Kharga Oases (A) area is located between latitudes 25°15′ and 26°05′ N and longitudes 30°05′ and 30°45′ E, Fig. 1 shows its ETM$^+$ image. Al-Kharga Oases (B) area is located between latitudes 24°20′ and 25°20′ N and longitudes 30°15′ and 30°50′ E (Fig. 2). Al-Kharga Oases, known to the ancient Egyptians as the 'Southern Oases', are the largest Oases of the western desert and consist of a depression about 160 km long and from 20 to 80 km wide. Today it is often referred to as the 'Great Oasis' and considered as the capital of the New Valley Governorate.

Al-Dakhla Oases (A) area is located between latitudes 25°00′ and 25°45′ N and longitudes 28°30′ and 29°30′ E, as displayed on the ETM$^+$ image (Fig. 3). Al-Dakhla Oases (B) area

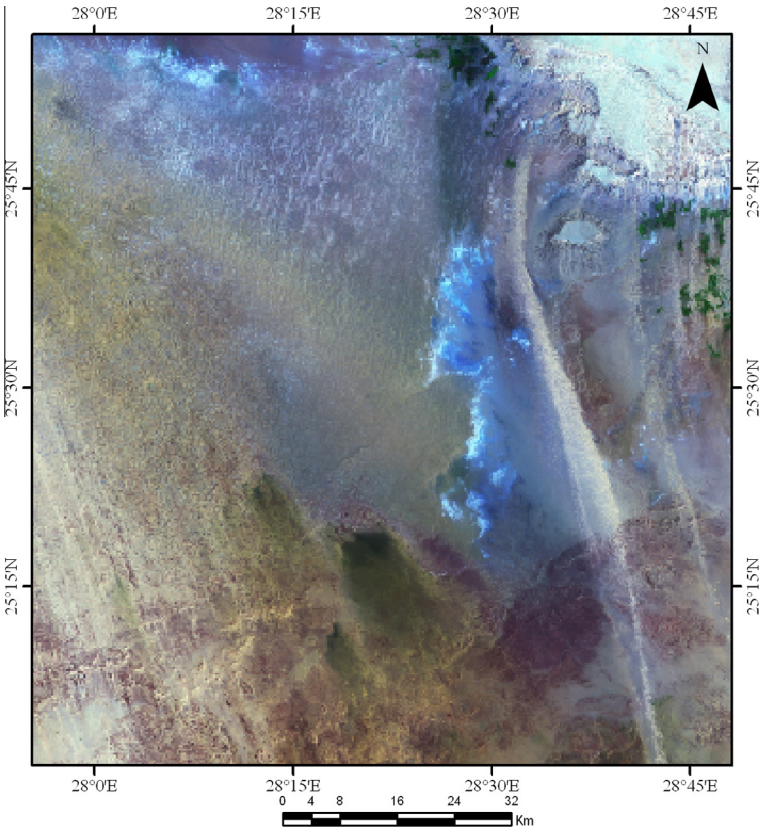

Figure 3 ETM$^+$ Landsat images of Al-Dakhla Oases (A).

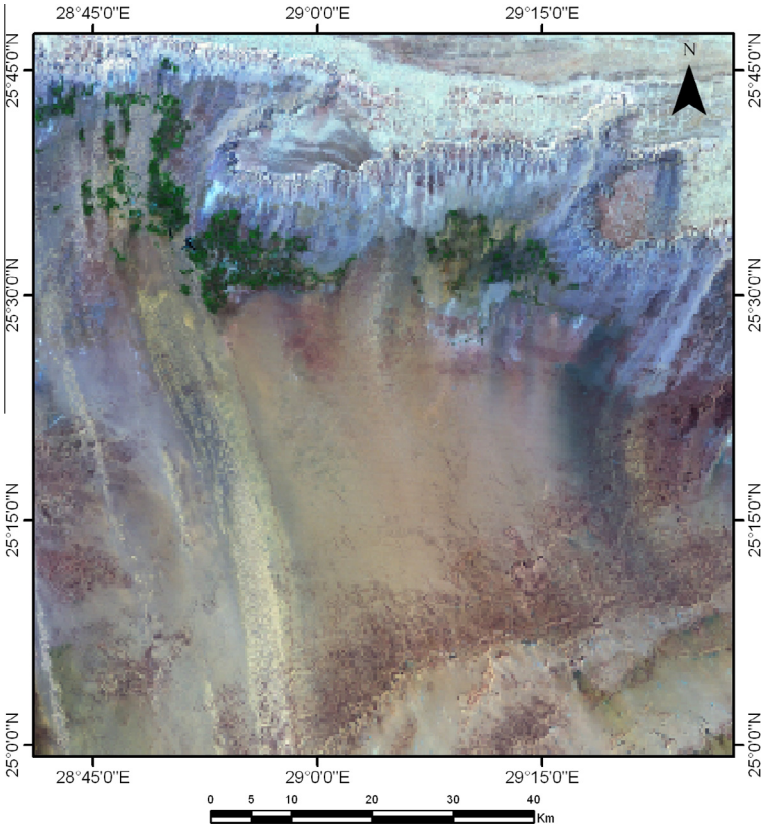

Figure 4 ETM$^+$ Landsat images of Al-Dakhla Oases (B).

Table 1 Description of land capability classes, adapted from Sideruis (1984) and FAO (1985).

Rating	Capability classes	Description
I	Very highly capable	Very low grade of liability/absence of risk
II	Highly capable	Low grade of liability/low risk
III	Moderately capable	Medium grade of liability/medium risk
IV	Low capable	High grade of liability/high risk
V	Very low capable	Very high grade of liability/very high risk

Table 2 Rating drainage conditions land quality.

Drainage class	Class	Rating
Excessively, somewhat excessively and well drained	Very low liability	I
Moderately well drained	Low liability	II
Imperfectly drained	Moderate liability	III
Poorly drained	High liability	IV
Very poorly drained	Very high liability	V

Table 3 Rating soil consistency and structure for land qualities.

Structure	Consistence			Rating
	Dry	Moist	Wet	
Granular	Loose, slightly hard	Loose, friable	Non-sticky, non plastic	I
Medium blocky	Hard	Friable, firm	Slight sticky, slight plastic	II
Coarse blocky	Very hard	Very firm	Sticky and plastic	III
Platy, massive	Extremely hard	Extremely firm	Very sticky, very plastic	IV
—	Rock	Rock	—	V

(Fig. 4) is located between latitudes 25°00′ and 25°55′ N and longitudes 28°00′ and 28°50′ E. Al-Dakhla Oases was known in ancient times as ''Zeszes'', the place of two swords because it is divided into two distinct areas. It is an area of about 2000 km^2 bounded on the west by the Great Sand Sea, on the north by a high limestone escarpment and on the east by Abu-Tartur Plateau. Al-Dakhla is the second most highly populated region in the New Valley region. There is evidence that Al-Dakhla, like other desert regions, has been inhabited since Prehistoric times. When the region gradually became more arid, inhabitants began to move closer toward the sources of water.

3. Materials and methods

ETM^+ images of 2004, covering Al-Kharga and Al-Dakhla Oases, Egypt, were used in the present study. The space images were collected and processed to be included in the GIS land resource database. They were also used in the thematic mapping processes. SPOT images of 2006 were processed for updating different thematic maps and detecting changes in land use/land cover.

Pre-processing commonly comprises a series of sequential operations, including radiometric correction or normalization, image registration, geometric correction, masking and image enhancement (e.g., for clouds, water, irrelevant features). In the current work, different functions of ERDAS IMAGINE (Ver. 9.2) were used for all processing steps. The digital maps were corrected for different errors and edge-matched after the geo-referencing processes.

The DEM of Al-Kharga and Al-Dakhla Oases have been generated from the elevation points (Spot heights) and vector contour lines, using *Topo to Raster* function of ArcGIS system.

Table 4 Rating soil depth for land quality.

Soil depth in (cm)	Class	Rating
Very deep (> 120)	Very low liability	I
Deep (80–120)	Low liability	II
Moderately deep (50–80)	Moderate liability	III
Shallow (25–50)	High liability	IV
Very shallow (< 25)	Very high liability	V

Table 5 Rating %$CaCO_3$ for land quality.

$CaCO_3$%	Class	Rating
(< 8)	Very low liability	I
(8–12)	Low liability	II
(12–16)	Moderate liability	III
(16–35)	High liability	IV
(> 35)	Very high liability	V

Table 6 Rating CEC, EC and ESP land qualities.

CEC Meq/100 G. soil	EC dS/m	ESP	Class	Rating
> 24	0–2	0–10	Very low liability	I
16–24	2–4	10–20	Low liability	II
12–16	4–8	20–35	Moderate liability	III
6–12	8–16	35–50	High liability	IV
< 6	> 16	> 50	Very high liability	V

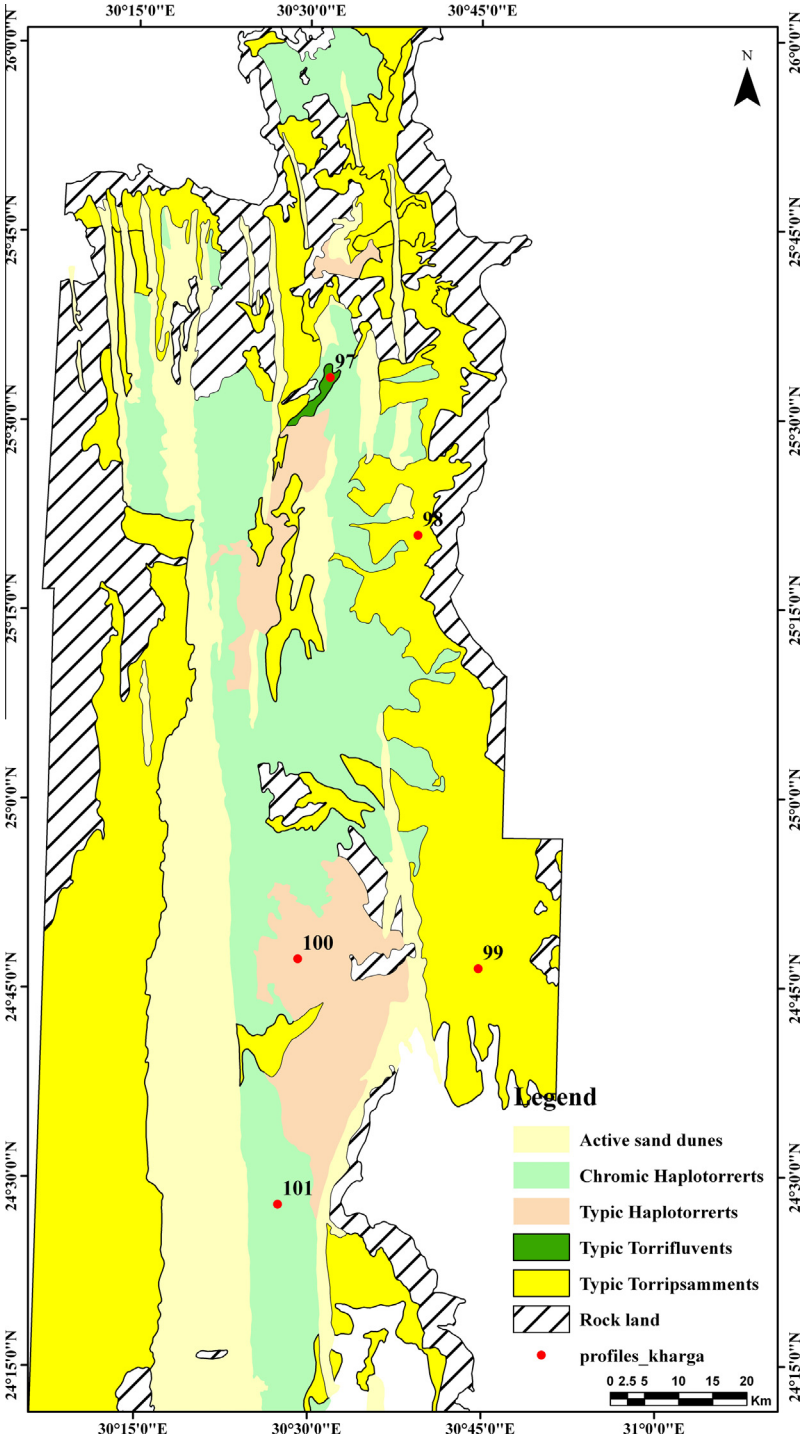

Figure 5 Geographical distribution of the studied soil profiles of Al-Kharga Oases.

Soils and land capability maps of Al-Kharga and Al-Dakhla Oases were developed in GIS format at a scale 1:100,000. The soil maps of Egypt (ASRT, 1982) at scale of 1: 100,000, in analogue format, were the main data source collected and converted into digital form.

Collected soil samples, representing, different soil units of the studied region, have been analyzed in the lab for soil chemical and physical characteristics. The results of these analyses have been compiled in database tables and then incorporated into the attribute tables of the digital GIS ready soil maps (Nguyen Quec Dinh, 2001; Pavasovic, 1993) in order to be used later in different applications.

Land capability classes were defined according to the rating of soil properties adapted from Sideruis (1984). The influence of each land quality is determined by a set of interacting single or compound land characteristics. Each land quality was assessed qualitatively according to its liability to the concerned constraints as shown in Table 1.

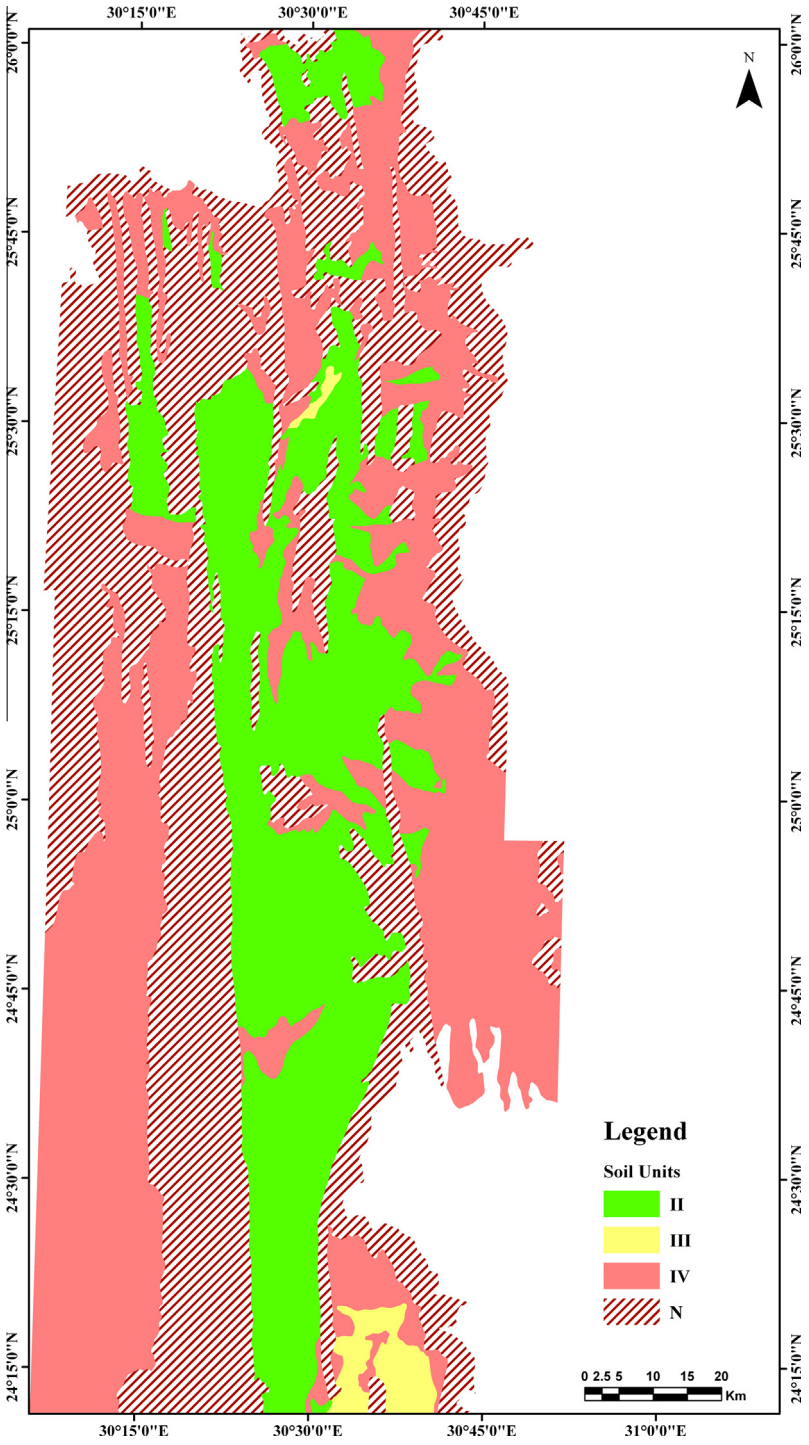

Figure 6 Land capability classes Al-Kharga Oases.

Table 7 Areas of Al-Kharga Oases land capability classes.

Capability class	Area (km^2)	Area (%)
II	2928.5	24.5
III	182.3	1.5
IV	4313.2	36.0
N	4555.7	38.0
Total	11979.7	100.0

The distinction between classes are defined in common numerical terms, thus permitting objective comparison between different kinds of land use. The assessment of land quality was based on several factors (i.e. drainage conditions, soil texture and structure, % coarse fragments, soil depth, % $CaCO_3$, CEC, soil salinity, expressed by electric conductivity of 1:1 soil solution (EC) and exchangeable sodium percentage (ESP) values. The rating values, assigned to each of the land quality, are demonstrated in Tables 2–6.

The land capability maps were produced using Arc – GIS 10.2 software, depending on the capability classes calculated in the established database.

4. Results and discussion

4.1. Land capability classification of Al-Kharga Oases

Al-Kharga Oases were represented by a number of 5 soil profiles, shown in Fig. 5 indicating different soil taxonomy units. Fig. 6 shows the land capability classification and the main land qualities of Al-Kharga Oases, different classes and their areas are shown in Table 7. The obtained data indicate that the highly capable soils (Class II) represent 24.5% of the Oases; associated with the *Typic Haplotorrerts* and *Typic Torrifluvents* sub-great groups, and are found mainly in the middle parts of the Oases. The moderately capable soils (Class III) represent 1.5% of the total area; associated with the soils of *Typic Torriorthents*, and exhibit the southwestern corner of the depression. The low capable soils represent 36.0% of the total area; this class is associated with the soils of the *Torripsamments* great group and are found mainly closed to the depression margins. The rest of the Oases are considered as non-capable soils or rock land, representing 38.0% of the total area.

4.2. Land capability classification of Al-Dakhla Oases

Gad (2011) indicated that the main soil units, representing Al-Dakhla Oases include five sub-great groups (i.e. *Typic Torrifluvents*, *Typic Haplotorrert*, *Chromic Haplotorrerts*, *Typic Torripsamments*, *Lithic Torripsamments*). A number of 5 soil profiles (Fig. 7) were used in this study for the purpose of land capability classification. Fig. 8 shows the land capability classification and main land qualities of Al-Dakhla Oases, different classes and their areas are shown in Table 8. The obtained data indicate that the highly capable soils (Class II) represent 19.2% of the Oases; it is associated with the *Typic Torrifluvents*, *Typic Haplotorrerts* and *Chromic Haplotorrerts*

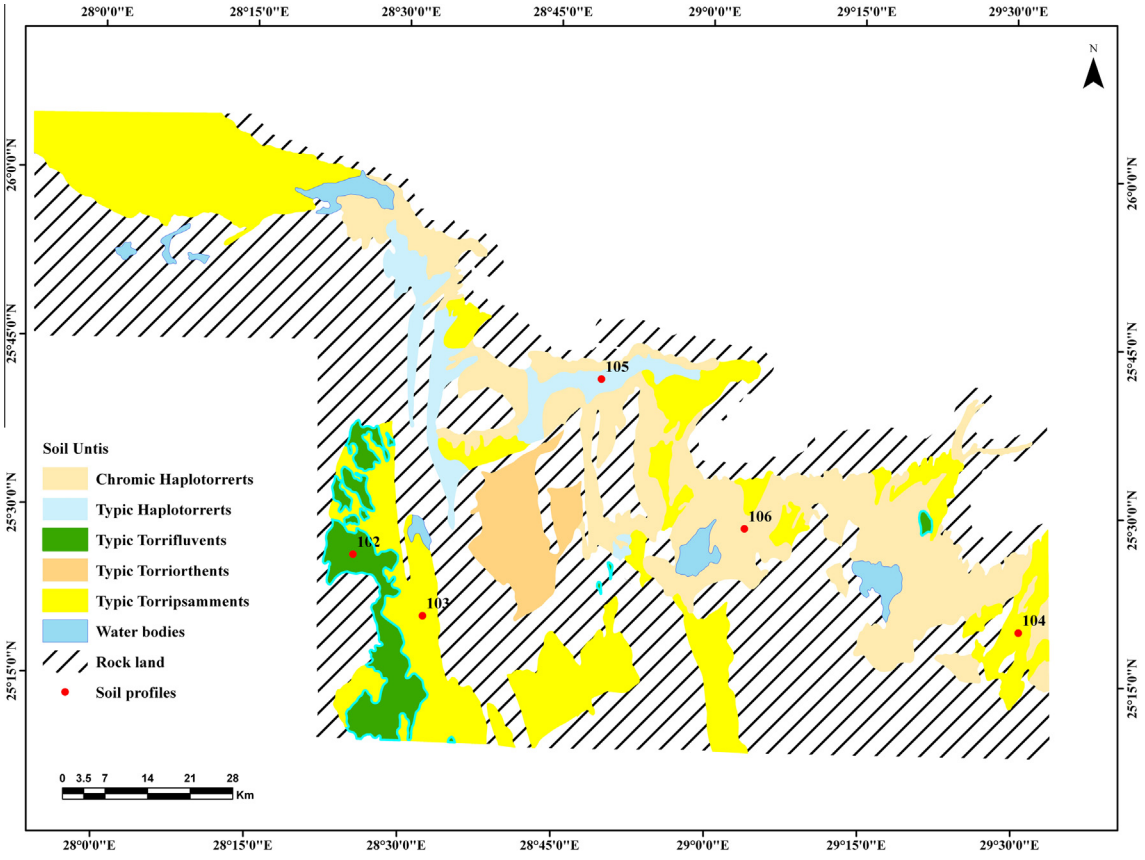

Figure 7 Geographical distribution of the studied soil profiles of Al-Dakhla Oases.

Table 8 Land capability classes of Al-Dakhla Oases.

Capability class	Area (km^2)	Area (%)
II	1816.1	19.2
III	573.1	6.1
IV	1920.2	20.3
N	5153.1	54.5
Total	9462.6	100.0

sub-great group, and is found mainly in the northern parts of the Oases. The moderately capable soils (Class III) represent 6.1% of the total area; it is associated with the soils of *Typic Torripsamments*, exhibiting some patches in the western side of the depression. The low capable soils represent 20.3% of the total area; this class is associated with the soils of *Lithic Torripsamments* sub-great group and found mainly closed to the depression margins or adjacent to the active sand dunes. The rest of the Oases are considered as non capable soils, rock land or active sand dunes, these units represent 54.5% of the total area.

The land capability classes and limiting factors of Al-Dakhla and Al-Kharga Oases are shown in Table 9. The data refer that soil salinity, as a capability limiting factor, is often reaching the worst level (sub-class 4) in the Oases. This character is related to the high water table level, which was found at

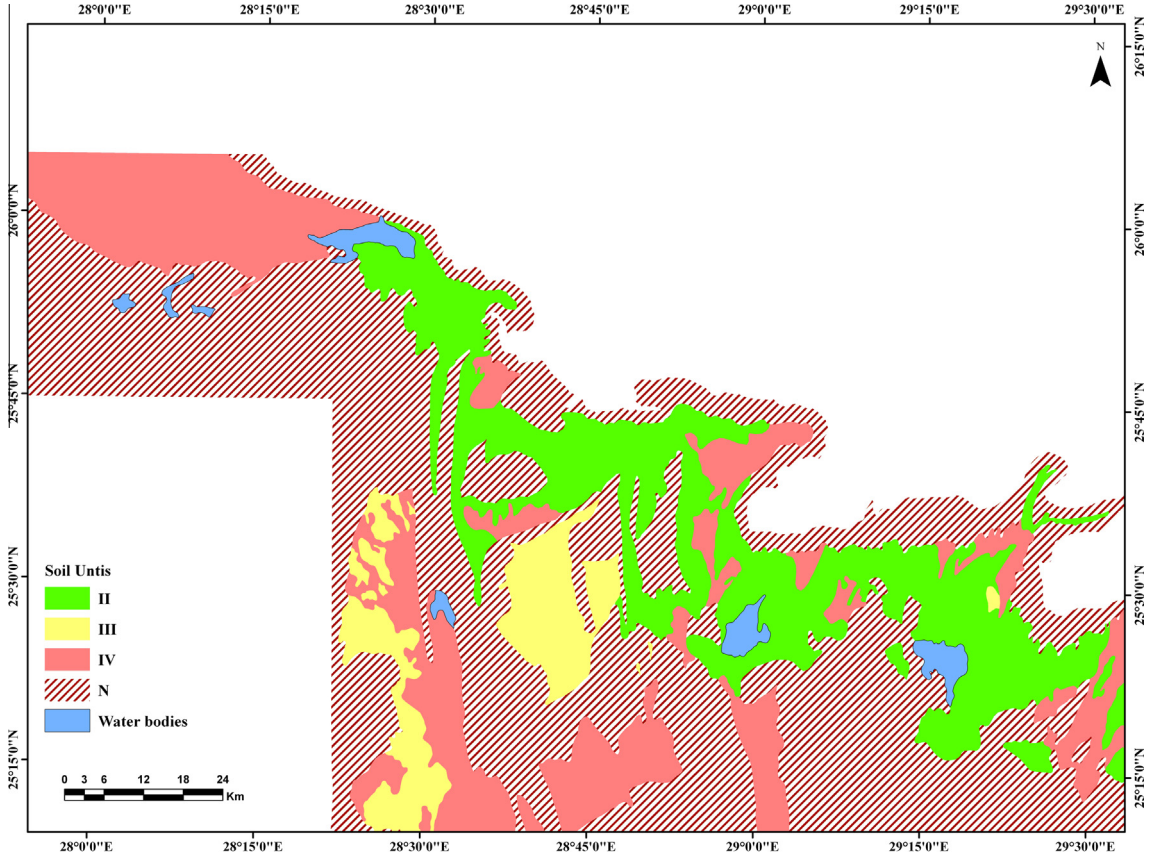

Figure 8 Land capability classes Al-Dakhla Oases.

Table 9 Land capability classes and limiting factors of the western desert Oases representative profiles.

Factors	Al-Kharga Oases					Al-Dakhla Oases				
	1	2	3	4	5	1	2	3	4	5
Soil depth	1	3	1	1	1	1	3	3	1	1
Texture/Structure	1	3	3	1	1	1	1	1	1	1
% Coarse fragments	2	2	2	2	1	1	1	1	1	1
Drainage condition	1	3	1	1	1	1	3	3	1	1
% $CaCO_3$	1	1	1	1	1	1	1	1	2	1
CEC Meq/100 g. soil	1	2	3	1	1	1	1	1	1	2
$ECe_{(1:1)}$ dS/m	3	1	2	2	3	2	2	2	4	1
ESP	2	2	3	1	1	1	3	2	3	2
Capability class	III	III	III	II	III	II	III	III	IV	II
Limiting factors	E	D,T,L	T,F	–	E	–	D,L,S	D,L	E,S	–

45 cm depth, from soil surfaces, adjacent to the swamps and lakes.

The soil texture is considered mostly as a common limiting factor in Al-Kharga Oases. The soil texture is rather coarse (sub-class III) in the *Typic Torripsamments* and *Typic Quartizpsamments* soils sub-great groups, which dominates Al-Dakhla and Al-Kharga Oases. The CEC factor, referring to soil fertility, is associated with soil texture. The CEC severity level is high in the *Typic Torripsamments* and *Typic Quartizpsamments* soils sub-great groups.

Drainage condition is associated with the soil depth and texture, the shallower the soil depth and finer the soil texture, the worst the drainage condition. The severity of drainage conditions varies from moderate to high level in the Oases. Coarse fragments percentage and $CaCO_3$ content reflect different severity levels ranging from low to high sub classes in the Oases.

5. Conclusion

It could be concluded that the highly capable soils (Class II) in both Al-Kharga and Al-Dakhla Oases are found associated with the *Typic Haplotorrerts*, *Typic Torrifluvents* and *Chromic Haplotorrerts* sub-great soil groups. They exhibit mainly the middle parts of Al-Khaga and northern parts of Al-Dakhla Oases. The low capable soils in both Al-Dakhla and Al-Kharga are associated with the soils of *Torripsamments* great group and found mainly close to the depressions margins. The Oases are significantly exhibited by non-capable land units as rock land, Eolian deposits and sabkhas.

It is obvious that the desert Oases are sustainable areas, which might have potential importance supporting the national development programs. Integrating remote sensing data with digital soil map, using GIS, led to the elaboration of accurate land capability classification mapping.

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